What are the health risks of PP plastics in kit c en appliances and food processing?

PP plastics in kitchen appliances and food processing release microplastics, nanoplastics, and chemical migrants—including potentially carcinogenic and endocrine-disrupting compounds—that cause meta olic disruption and cytotoxicity in animal and cellular models, though the clinical significance of these effects at typical human exposure levels remains uncertain.

Abstract

This systematic review of 10 sources identifies two primary categories of health-relevant su stances released from polypropylene (PP) plastics in food contact applications: particulate matter and chemical migrants. PP food containers, infant feeding ottles, and cookware release su stantial quantities of microplastics and nanoplastics, with concentrations reaching up to 16.2 million particles per liter during infant formula preparation and 4.22 million microplastics per square centimeter within 3 minutes of microwave heating . Chemical migrants include antioxidant additives (Irganox 1076, Irganox 1010, Irgafos 168) accounting for 83% of migration into fatty foods , and degradation products such as 2,6-DTBQ with mechanistic evidence of carcinogenic risk . Temperature consistently emerges as the most critical risk factor, with microwave heating and sterilization su stantially increasing oth particle and chemical release .

Evidence of health effects comes primarily from animal and cellular studies. Mice fed diets heated in PP containers for 8 weeks exhi ited meta olic disruption including liver steatosis, altered fasting lood glucose, and changes in serum lipid profiles . In vitro studies demonstrate cytotoxicity (approximately 77% cell death at 1000 μg/mL) and immune stimulation with increased cytokines and histamines at high concentrations of small PP particles . However, a significant gap exists etween exposure characterization and health outcome data: the concentrations causing cytotoxicity in vitro su stantially exceed estimated real-world daily intakes of 20-22 ng/kg·day , making direct risk extrapolation to humans pro lematic. While the evidence supports concern a out PP plastics as sources of potentially hazardous su stances, the clinical significance of typical human exposure levels remains inadequately characterized .

Paper sear c

We performed a semantic search using the query "What are the health risks off PP plastics in kitchen appliances and food processing?" across over 138 million academic papers from the Elicit search engine, which includes all of Semantic Scholar and OpenAlex.

We retrieved the 50 papers most relevant to the query.

Screening

We screened in sources ased on their a stracts that met these criteria:

- **Polypropylene Plastic Focus**: Does this study specifically investigate polypropylene (PP) plastic exposure with clear methodology for PP identification?
- **Food Contact Exposure Pathway**: Does the PP exposure occur through kitchen appliances, food processing equipment, or food contact materials made of PP?
- **Health-Relevant Outcomes**: Does this study measure or assess health outcomes, iomarkers, toxicological effects, OR PP-related chemical migration into food/ everages?

- Appropriate Study Design: Is this study one of the following: human epidemiological study (cross-sectional, cohort, case-control), animal/in vitro toxicological study, or systematic review/meta-analysis?
- PP-Speci f c E f ects Determinable: Can PP-specific effects e determined from this study (i.e., the study does NOT have unclear or mixed plastic exposures where PP effects cannot e isolated)?
- PP Data Available: Does this study include PP-specific data (i.e., it does NOT focus solely on other plastic types like PET, PVC, PS without PP data)?
- Food Contact Route: Does this study examine PP exposure through food contact routes (i.e., it does NOT focus solely on non-food contact routes like textiles or automotive parts)?
- Health Risk Assessment Focus: Does this study address health outcomes, toxicological effects, or chemical migration (i.e., it does NOT focus only on environmental contamination or physical properties without health assessment)?

We considered all screening questions together and made a holistic judgement a out whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column elow from each paper. We gave the model the extraction instructions shown elow for each column.

- PP Application Type:

  Extract details a out the polypropylene application studied including:

- Type of item (food container, packaging film, kitchen appliance, etc.)
- Intended use (hot food storage, cold storage, heating/cooking, etc.)
- Any specific product details or rand information
- Whether new or used/aged materials were tested

- Health E f ects Identi f ed:

  Extract all health risks, effects, or toxicity findings including:

- Specific health outcomes o served (meta olic disruption, cytotoxicity, immune responses, etc.)
- Target organs/systems affected (liver, immune system, etc.)
- Severity or magnitude of effects
- Dose-response relationships if reported
- Both acute and chronic effects

- Exposure Me c anism:

  Extract how PP plastic components reach humans including:

- Type of exposure (chemical migration, particle release, volatile emissions)
- Specific pathways (ingestion, inhalation, dermal contact)
- Rate of migration/release if quantified
- Whether exposure was direct contact or indirect

- Harmful Substances:

  Extract details a out specific compounds or particles causing health risks including:

- Chemical names and concentrations of migrants (additives, degradation products, etc.)
- Particle types and sizes (microplastics, nanoplastics)

- Molecular weight and chemical properties
- Known toxicity classification if mentioned

- Risk Conditions:

  Extract conditions that influence health risk level including:

- Temperature exposure (heating, cooking, sterilization temperatures)
- Contact time/duration
- Type of food or liquid in contact (fatty foods, acidic, aqueous)
- Environmental stressors (UV, oxidation, mechanical stress)
- Usage patterns that increase risk

- Study Model:

  Extract the experimental approach used including:

- Type of study (in vitro, in vivo, human exposure, simulation)
- Model system (cell lines, animal species, human su jects)
- Exposure duration and conditions
- Sample size if applica le

- Risk Magnitude:

  Extract quantitative measures of health risk including:

- Concentration levels of harmful su stances detected
- Biological effect measurements (gene expression changes, meta olic markers, etc.)
- Comparison to safety thresholds or regulatory limits
- Risk assessment conclusions
- Statistical significance of findings

- Food Context:

  Extract details a out food-related scenarios including:

- Types of foods tested (fatty, acidic, dry, liquid)
- Food preparation methods (heating, microwaving, storage)
- Real-world usage scenarios simulated
- Food contact time and temperature
- Comparison   etween different food types

Characteristics of Included Studies

This review synthesizes evidence from 10 sources examining health risks associated with polypropylene (PP) plastics used in kitchen appliances and food processing contexts. The included studies span from 1993 to 2024 and employ diverse methodological approaches.

Study	Full text retrieved?	Study Type	PP Application	Model System
Hu Liu et al., 2024	No	Primary study (in vitro/in vivo)	Heat-treated PP food containers	AML12 hepatocytes; C57BL/6J mice

Study	Full text retrieved?	Study Type	PP Application	Model System
Kazi Al a Hussain et al., 2023	Yes	Primary study (simulation/in vitro)	PP- ased plastic containers for microwave heating, refrigeration, storage	HEK293T cells
E. Moreno-Gordaliza et al., 2023	No	Primary study (in vitro)	Reusa le silver-containing PP food containers	Food simulants
Ying Wang et al., 2023	Yes	Primary study (simulation)	PP takeaway oxes for hot food storage	Multiple plastic packaging materials
Dunzhu Li et al., 2020	Yes	Primary study (in vitro)	PP infant feeding ottles	Ten representative PP-IFB products
Tuárez Párraga et al., 2022	Yes	Bi liographic review	PP containers for fatty foods	Not applica le
Jangsun Hwang et al., 2019	No	Primary study (in vitro)	PP microplastics (not application-specific)	PBMCs, Raw 264.7, HMC-1 cells
B. Geueke et al., 2023	Yes	Data ase review	PP food containers, films, ags, ottle caps	Data ase analysis (FCCmigex)
J. Boone et al., 1993	No	Review	PP food packaging materials	Not applica le
Matthew Cole et al., 2024	No	Primary study (simulation)	Plastic cookware (new and old)	Jelly food simulant

The studies examined various PP applications relevant to food contact, including food containers for heating and storage , takeaway oxes , infant feeding ottles , packaging for fatty foods , and cookware . Study designs ranged from in vitro cellular models to in vivo animal studies, with three sources eing literature reviews . Both new and used/aged materials were examined across studies, providing insight into PP ehavior throughout product lifecycles.

Harmful Substances Identi f ed

The reviewed literature identifies two primary categories of health-relevant su stances released from PP plastics: particulate matter (microplastics and nanoplastics) and chemical migrants.

Particle Release

Source	Particle Type	Size Range	Release Magnitude
Kazi Al a Hussain et al., 2023	Microplastics and nanoplastics	Not specified	Up to 4.22 million microplastics and 2.11 illion nanoplastics per cm² within 3 minutes of microwave heating
Ying Wang et al., 2023	Nanoplastics	50-400 nm	O served in PP groups su jected to 100℃ hot water
Dunzhu Li et al., 2020	Microplastics and nanoplastics	Microplastics <20 μm; nanoplastics ~100 nm	Up to 16,200,000 particles per liter
E. Moreno-Gordaliza et al., 2023	Silver-containing microplastics	Not specified	Significant amounts detected in food simulants
Jangsun Hwang et al., 2019	PP microplastics	~20 μm and 25-200 μm	Experimental exposure study
Matthew Cole et al., 2024	Microplastics (PTFE, polyethylene, polypropylene)	13-318 μm	2,409-4,964 microplastics per annum from daily cookware use

Particle release from PP materials represents a consistent finding across studies. Infant feeding ottles released microplastics at concentrations as high as 16,200,000 particles per liter during formula preparation , while microwave heating of PP containers released up to 4.22 million microplastic and 2.11 illion nanoplastic particles per square centimeter within just 3 minutes . Glo al infant exposure estimates ranged from 14,600 to 4,550,000 particles per capita per day depending on regional feeding practices .

Chemical Migrants

Source	Chemical Compounds	Migration Levels
Tuárez Párraga et al., 2022	Irganox 1076, Irganox 1010, Irgafos 168	83% of total glo al migration
B. Geueke et al., 2023	2,4-DTBP, 2,6-DTBQ	10-100 μg/kg food for 2,4-DTBP
E. Moreno-Gordaliza et al., 2023	Ionic silver, nanoparticulated silver	Exceeded European safety recommendations in some containers

Chemical migration from PP involves primarily antioxidant additives and their degradation products. Three antioxidants—Irganox 1076, Irganox 1010, and Irgafos 168—account for 83% of chemical migration from PP containers into fatty foods . The degradation products 2,4-DTBP and 2,6-DTBQ are regularly detected in migrates from PP products at levels of 10-100 μg/kg food . Nota ly, 2,6-DTBQ demonstrates mechanistic evidence indicating carcinogenic risk , while 2,4-DTBP is eing evaluated as an endocrine disruptor .

Health E f ects

Metabolic and Systemic E f ects

Source	Model	Health Outcomes	Magnitude
Hu Liu et al., 2024	AML12 hepatocytes; C57BL/6J mice	Disrupted lipid/glucose meta olism, increased intracellular lipid content, liver steatosis, glycogen accumulation	Accelerated ody weight gain over 8 weeks; altered fasting lood glucose; increased adipocyte size
Dunzhu Li et al., 2020	Literature reference	Gut micro iota dys iosis, lipid meta olism disorder (mice); rain damage, ehavioral disorders (fish)	Significant effects in animal studies

The most comprehensive toxicological data comes from Hu Liu et al. (2024), demonstrating that leachates from heat-treated PP containers caused significant meta olic disruption in oth cell and animal models . Mice fed diets heated in PP containers for 8 weeks exhi ited accelerated ody weight gain, altered fasting lood glucose levels, and changes in serum lipid profiles . Histological analysis revealed liver steatosis, increased adipocyte size, and glycogen accumulation , with transcriptome sequencing confirming significant alterations in meta olic pathway gene expression .

Cytotoxicity and Immune E f ects

Source	Cell Type	Effect	Concentration/Conditions
Kazi Al a Hussain et al., 2023	HEK293T cells	76.70% cell death (48h); 77.18% cell death (72h)	1000 μg/mL microplastics/nanoplastics
Jangsun Hwang et al., 2019	PBMCs, Raw 264.7, HMC-1	Increased cytokines and histamines; enhanced hypersensitivity	High concentration, small sized PP particles

Cytotoxicity assessments demonstrate dose-dependent effects. Microplastics and nanoplastics extracted from PP containers caused death of approximately 77% of human em ryonic kidney cells at 1000 μg/mL concentration . Jangsun Hwang et al. (2019) found that while PP particles showed low cytotoxicity overall, high concentrations of small-sized particles (~20 μm) stimulated immune responses and enhanced hypersensitivity through increased cytokine and histamine levels in immune cells . Potential health risks identified include cytotoxicity, hypersensitivity, unwanted immune response, and acute responses such as hemolysis .

Regulatory Exceedances

Several studies documented exceedances of esta lished safety thresholds. Silver migration from antimicro ial PP containers exceeded European authorities' safety recommendations in some products . The tolera le daily intake (TDI) for isphenol A (0.2 ng/kg ody weight/day) is exceeded y two to three orders of magnitude in actual exposure scenarios , though this finding applies more roadly to plastic food contact materials rather than PP specifically.

Exposure Me c anisms and Risk Conditions

Exposure Pathways

All studies identifying exposure mechanisms reported ingestion as the primary pathway , with chemical migration and particle release eing the two dominant exposure types. Inhalation and contact with food packaging were also noted as potential routes .

Temperature E f ects

Source	Temperature Condition	Effect on Release
Kazi Al a Hussain et al., 2023	Microwave heating vs. refrigeration/room temperature	Microwave heating caused highest release
Dunzhu Li et al., 2020	25℃ to 95℃ range	Higher temperatures significantly increase microplastic release
E. Moreno-Gordaliza et al., 2023	Conventional vs. microwave heating	Silver migration increased with temperature
Ying Wang et al., 2023	100℃ and 121℃	NP release o served at high temperatures
B. Geueke et al., 2023	Elevated temperatures, microwave heating	Microwave heating has stronger effects than conventional heating on 2,4-DTBP migration

Temperature emerges as the most critical risk factor. Microwave heating consistently produced the highest release of oth particles and chemical migrants across studies . Sterilization at 100℃ increased microplastic release from infant feeding ottles y 35% to 84% . Higher temperatures (100℃, 121℃) triggered o serva le nanoplastic release from PP materials that was not detected at lower temperatures .

Food Type and Contact Duration

Risk Factor	Effect	Sources
Fatty foods	Increased migration due to lipophilic nature of packaging chemicals	Tuárez Párraga et al., 2022
Acidic foods	Increased silver and chemical migration	Moreno-Gordaliza et al., 2023; Hussain et al., 2023
Hydropho ic food simulants	Increased 2,4-DTBP migration	Geueke et al., 2023
Contact time	Longer times increase migration	Multiple sources
Long-term storage	Refrigeration and room-temperature storage for >6 months releases millions to illions of particles	Hussain et al., 2023
Repeated use	Increases risk; periodic fluctuations o served over 21 days	Multiple sources

The type of food in contact significantly influences migration rates. Fatty foods promote greater migration of lipophilic packaging chemicals , while acidic conditions increase oth silver and particle release . Prolonged storage, even under refrigeration, results in su stantial particle accumulation over months . Environmental stressors including thermal stress, oxidation, and radiation contri ute to PP degradation .

Estimated Human Exposure

Exposure modeling provides concerning estimates for vulnera le populations. Infants consuming formula from PP ottles may e exposed to 20.3 ng/kg·day of microplastics from microwaved water, while toddlers consuming microwaved dairy products face estimated intakes of 22.1 ng/kg·day . Regional variation in infant exposure is su -stantial, ranging from 14,600 to 4,550,000 particles per capita per day depending on reastfeeding practices and preferences for PP products . Daily preparation of meals using plastic cookware may contri ute 2,409-4,964 microplastics annually to homecooked food .

Synthesis

The evidence reveals consistent patterns of health risk from PP plastics in food contact applications, though the magnitude and clinical significance of these risks remain incompletely characterized.

Reconciling Particle Release Findings

While all studies examining particle release documented su stantial microplastic and nanoplastic generation from PP materials, the reported quantities span several orders of magnitude. This heterogeneity reflects methodological differences rather than contradictory findings: studies measuring release under microwave heating conditions report higher values than those examining am ient storage , consistent with the esta lished temperature-dependence of particle release. The highest exposure estimates (illions of nanoplastics per cm^2) occurred under aggressive microwave conditions, while more moderate estimates emerged from standard ottle preparation protocols .

Gaps Between Exposure and E f ect Data

A critical limitation in the current evidence ase is the disconnect etween exposure characterization and health outcome studies. The most rigorous health effects data comes from Hu Liu et al. (2024), demonstrating meta olic disruption in animals fed diets heated in PP containers . However, this study did not quantify the specific leachate concentrations causing these effects . Conversely, studies providing detailed particle quantification lack corresponding in vivo health outcome data. The in vitro cytotoxicity o served at 1000 µg/mL concentrations su stantially exceeds the estimated daily intake of 20-22 ng/kg·day , making direct risk extrapolation pro lematic.

Population-Speci f c Considerations

Infants represent a particularly vulnera le population due to the prevalence of PP infant feeding ottles , high feeding frequency, and the com ination of sterilization and formula preparation that maximizes particle release . The documented practice of microwave heating further amplifies exposure , despite WHO recommendations against microwave use for formula preparation . Regional differences in reastfeeding rates and PP product preferences create su stantial variation in infant exposure estimates .

Chemical vs. Particle Hazards

The evidence supports distinct concern pathways for chemical migrants versus particulate matter. Chemical migrants, particularly antioxidant degradation products such as 2,6-DTBQ with carcinogenic potential and 2,4-DTBP with endocrine-disrupting properties , present hazards ased on esta lished toxicological mechanisms. Particle effects are less well characterized; while high-dose in vitro studies demonstrate cytotoxicity and immune stimulation , the health implications of ingesting microplastics at typical exposure levels remain unclear .

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